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REPORT ON THE PINE TIPMOTH EXPERIMENTS NEBRASKA NATIONAL FOREST, HALSEY, NEBRASKA.

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REPORT ON THE PINE TIPMOTH EXPERIMENTS

NEBRASKA NATIONAL FOREST, HALSEY, NEBRASKA.

Since its introduction in the Nebraska National Forest at Halsey, Nebraska, the Pine tipmoth (Rhyacionia frustrana bushnelli Busck) has been an increasing menace to the plantations. Although it works in all species of pine planted in the sandhills, its chief destructiveness is to western yellow pine, the most valuable and widely planted species on the forest. The tipmoth is not only retarding height growth to a minimum and deforming the trees, but is actually killing the trees in some cases.

The pest was probably imported along with a few of its parasites, on forest-pulled stock from the Lake States which made up a part of the early plantations. Within a comparatively few years (1909) the prevalence of tipmoth injury made it evident that something would have to be done toward alleviating this annual destruction. Work on this problem was started in 1911 and 1912 by the State Entomologist of Nebraska but because of the pressure of other matters it was discontinued. During the season just passed the problem was resumed but this time under the direction of the Bureau of Entomology, U. S. D. A. Work on the problem is now being conducted co-operatively by the Forest Service and the Bureau of Entomology, U. S. D. A. Mr. Swenk, Nebraska State Entomologist, has very kindly turned over all of his notes concerning this insect and it is planned to publish a life history paper in co-authorship with him. Field work was carried on during the past season between April 1st and October 1st.

The general plan of procedure in attacking the problem was as follows:

1. To conduct throughout the season observations on life history and habits of the tipmoth to supplement and check work previously done.

2. Inasmuch as the pest is evidently carried to new plantations in nursery stock, the effect of chemicals were to be tested as dips on both the seedlings and tipmoth eggs.

3. To test the efficacy of promising insecticides in the field in an attempt to find a chemical means of control in private plantations.

4. To study and introduce parasites of the pine tipmoth from Virginia and to study local parasites and predators. The introduction of parasites was under the direction of Mr. Cushman of the U. S. National Museum.

5. To study the ecological factors controlling the pest by means of permanent plots to be established in various plantations over the forest.

6. To make daily weather observations in connection with this work and to make a study of soil composition, cover and temperature on various sites.

LIFE HISTORY AND HABITS.

Careful observations on the life history and habits of the tipmoth were made during the season. These observations were to supplement and check previous studies conducted by Mr. Swenk, Nebraska State Entomologist, and his assistant. Sufficient information is now at hand and a report on the life history of the Pine Tipmoth will be prepared for publication in the near future.

CHEMICAL EXPERIMENTS

The tipmoth is reported to be spreading into most of the small, private pine plantations owned by settlers in the sandhills of Nebraska. The settlers receive their trees free from Bessey Nursery at Halsey. Shipments are made in early spring about the time the first brood moths are ovipositing. The cause of this infestation has been attributed to the transportation of tipmoth eggs or pupae on or in the nursery stock.

With a view of finding some cheap and effective method of cleaning the nursery stock, experiments were carried on with a number of chemicals, using them as dips with both young seedlings and with Pine Tipmoth eggs. Then also there was the possibility, with a suitable ovicide, of establishing a new area of planting near the west boundary of the Forest far removed from the present infested plantations in which only clean stock would be planted, thus avoiding infestation for a number of years.

a. Dipping nursery stock.

Western yellow pine. 2 - 0 stock, was used in these experiments to determine the effect of the chemicals on coniferous seedlings. The trees were dipped in sets of 100 each and transplanted during the usual transplant operations in the nursery. Screen-topped cages were placed over these beds to exclude the tipmoth after treatment.

The chemicals were used at various strengths and the results obtained, as to effect on the seedlings, are given in Table I. With the exception of the nitrobenzol emulsion, which caused the death of the trees soon after planting, only a small percentage of mortality can be attributed directly

to chemicals. The principal chemical injury was the killing of the new tips. Due to an early spring, many of the seedlings had a new tip growth of several inches previous to treatment and as might be expected, this growth was susceptible to chemical injury. Had the treatment taken place previous to bud expansion, the amount of chemical injury might have been materially reduced. The column headed "Other Injury" refers to destroyed buds or broken tips resulting from handling.

Table I.

*Effect of Chemicals on Western Yellow Pine Seedlings.

No.	Chemical	Strength	% dead	%chem. injury	% other injury	% normal	Rank
1	Lime sulphur	1-9	7	33	1	59	7
2	" " with glue	1-9	13	60	2	24	17
3	" "	1-6	16	59	2	23	18
4	" " with glue	1-6	4	78	4	13	19
5	Nicotine sulphate	1-500	1	22	4	73	2
6	" "	1-300	8	16	7	69	3
7	" oleate	1-100	11	39	3	47	12a
8	" "	1-200	20	17	1	62	5
9	" "	1-400	37	19	6	38	15
10	" "	1-600	25	25	3	47	12b
11	Miscible oil "Sunoco"	1-10	12	32	4	52	10
12	" " "	1-15	6	29	4	61	6
13	" " "	1-20	4	25	3	68	4
14	Cresol dip	1-50	35	51	2	12	20
15	" "	1-75	15	37	8	40	14
16	" "	1-100	22	26	6	46	13
17	" "	1-250	19	21	5	55	9
18	" "	1-500	30	17	2	51	11
19	Nitrobenzol emulsion	5%	99	1		0	
20	" "	10%	100			0	
21	" "	15%	100			0	
22	" "	20%	100			0	
23	" "	25%	100			0	
24	Wilhelm oil emulsion	5%	66	33	1	0	
25	" " "	10%	45	52	1	2	24a
26	" " "	15%	40	58	0	2	24b
27	" " "	20%	20	79	0	1	25
28	" " "	25%	15	76	0	9	23
29	Wilhelm oil nicotine emulsion	25%	18	68	4	10	22
30	Wilhelm oil nicotine emulsion	20%	12	74	3	11	21
31	Wilhelm oil nicotine emulsion	15%	3	61	4	32	16
32	Wilhelm oil nicotine emulsion	10%	7	13	4	76	1
33	Wilhelm oil nicotine emulsion	5%	20	20	3	57	8
1.	Check set(not treated)		13		3	74	
2.	" " " "		17		16	67	
3.	" " " "		12		5	83	
4.	" " " "		36		15	49	
5.	" " " "		36		19	45	
6.	" " " "		28		15	57	
7.	" " " "		5		17	78	
8.	" " " "		7		9	84	

*These chemicals were all applied as dips. Two year old seedlings were treated in the spring at time of transplanting. Counts of these lots were made frequently throughout the season. The data presented in this table are the final results at the end of the summer.

The abnormally high mortality in sets No. 18, 24, 25, 26 and check set (untreated)No. 5 was probably caused by strong fumes of nitrobenzol from adjacent sets in the same cage that were dipped in that material. In check set No. 4 (untreated) the planting of one row high in the ground caused about half of the death loss recorded for these 100 trees.

The most promising dips, with reference to their effect upon the seedlings, as indicated by per cent of normality in Table I would be: nicotine sulphate, 1-500 and 1-300; the weaker solutions of wilhelm oil nicotine emulsion 5 and 10%; the miscible oil at 1-15 and 1-20; lime sulphur, 1-9; and possibly nicotine oleate.

b. Dipping eggs of the tipmoth.

To test the most promising dips eggs were obtained from second brood moths and treated in various stages of development, the number of eggs hatching being recorded. A number of eggs from each group were retained untreated as a check on fertility. The effect of the chemicals on hatching of eggs and the approximate fertility of the check groups is shown in Table II below.

Table II.
Effect of Chemicals on Tipmoth Eggs.

Chemical	Strength	No. sets.	No. eggs dipped	No. eggs as check	Hatching No.	Hatching %	Failing to hatch No.	Failing to hatch %
Lime sulphur	1-9	4	26		20	76.9	6	23.1
(untreated)	Check	4		26	25	96.1	1	3.9
Lime sulphur with	1-9	5	55		1	1.8	54	98.2
glue	Check	5		29	28	96.5	1	3.5
Nicotine sulphate	1-100	2	14		2	14.3	12	85.7
	Check	2		10	8	80.0	2	20.0
" "	1-300	2	34		19	55.9	15	44.1
	Check	2		13	12	92.3	1	7.7
" "	1-500	2	16		2	12.5	14	87.5
	Check	2		13	13	100.00		0
" oleate	1-100	2	20		0		20	100.0
	Check	2		17	10	58.8	4	41.2
" "	1-200	1	23		0		23	100.0
	Check	1		11	10	90.9	1	9.1
" "	1-300	2	21		1	4.8	20	95.2
" "	Check	2		14	8	57.1	6	42.9
" "	1-400	1	15		4	26.7	11	73.3
	Check	1		8	7	87.5	1	12.5
# "	1-500	2	23		6	26.1	17	73.9
	Check	2		12	11	91.7	1	8.3
Miscible oil "Sunoco"	1-15	3	17		0		17	100.0
	Check	3		20	17	85.0	3	15.0
" " "	1-20	4	24		0		24	100.0
	Check	4		25	22	88.0	3	12.0
Cresol dip	1-25	1	9		5	55.6	4	44.4
	Check	1		14	10	71.4	4	28.6
" "	1-75	2	21		16	76.2	5	23.8
	Check	2		20	15	75.0	5	25.0
" "	1-100	1	11		9	81.8	2	18.2
	Check	1		8	7	87.5	1	12.5
" "	1-250	2	31		26	83.9	5	16.1
	Check	2		18	11	61.1	7	38.9
" "	1-500	2	13		11	84.6	2	15.4
	Check	2		21	18	85.7	3	14.3
Wilhelm oil nico-tine emulsion	10%	2	30		0		30	100.0
	Check	2		16	14	87.5	2	12.5
Wilhelm oil nico-tine emulsion	5%	3	64		10	15.6	54	84.4
	Check	3		31	30	96.8	1	3.2

The most promising dips, with reference to their effect upon tipmoth eggs, as indicated by 100% effectiveness against hatching are: nicotine oleate in the stronger solutions, 1-100 and 1-200; the miscible oil, 1-15 and 1-20; and the 10% wilhelm oil nicotine emulsion.

Miscible oil, a brand known as "Sunoco" being used, was the most consistent dip considering the results from both seedlings and eggs.

c. Dusting plantations.

Insecticides in dust form have been used successfully against various pests, both on a limited and extensive scale. If an effective insecticide could be found for the tipmoth there was a posibility of control by this method, at least for private plantations. Or if the pest could be reduced in numbers the parasites might have a chance of holding it in check.

The fact that the eggs of the tipmoth are laid on the needles and shoots of pine trees and the larvae work or feed on the outside for a time before burrowing into the buds or stems made it seem plausible that either a contact or stomach insecticide might give good results. As a test both forms of insecticides were tried on western yellow pine using positive calcium arsenate dust and nicotine dust.

For the first brood larvae the insecticides were applied during various stages of larval development, some plots being dusted a number of times. For the second brood larvae calcium arsenate was applied just previous to hatching in an attempt to poison the young larvae before they entered the buds. Following each brood the percentage of injured tips in the dusted plots were recorded and compared with an equal number of adjacent, undusted trees. The results of these dusting experiments are shown in the following tables:

Table III.

Percentage of injury on dusted and undusted trees - first brood larvae.

Plot	Insecticide	No. trees	Ave. height	Times dusted	Total no.tips	No. tips killed	% tips killed
A.	Cal. arsenate	10	4.4'	4	629	84	13.3
B.	Nicotine dust	10	4.0'	4	606	157	25.9
Check on A.and B.		10	4.25'	0	610	130	21.3
C.	C. arsenate	25	4.6'	2	1540	375	24.3
Check on plot C.		25	5.13'	0	1448	348	24.0
D.	Nicotine dust	25	4.67'	2	1669	518	31.0
Check on plot D.		25	3.89'	0	1449	338	23.3
E.	Nicotine dust	10	4.2'	1	619	159	25.6
Check on plot E.		10	4.8'	0	599	138	23.0
F.	Cal. arsenate	10	4.6'	1	603	154	25.5
Check on plot F.		10	5.1'	0	717	219	30.5

Table IV.

Percentage of injury on dusted and undusted trees - second brood larvae.

Plot	Insecticide	No. trees	Ave. height	Times dusted	Total no. tips	No.tips killed	% tips killed
G.	Cal. arsenate	25	3.34'	1	1154	480	41.5
Check on plot G.		25	3.57'	0	1243	598	48.1
H.	Cal. arsenate	25	4.28'	1	1315	612	46.5
Check on plot H.		25	3.71'	0	1248	799	64.0
I.	Cal. arsenate	10	4.47'	1	574	182	31.7
Check on plot I.		10	4.92'	0	626	394	62.9
J.	Cal. arsenate	10	4.3'	1	587	287	48.8
Check on plot J.		10	4.72'	0	722	402	55.6

The results obtained showed that neither of the insecticides was sufficiently effective to warrant its extensive application, although positive calcium arsenate when applied just before the eggs hatched reduced the injury somewhat as shown in Table IV.

The failure of the insecticides may be accounted for by the habit which the larvae have of spinning a protective web, which is coated with pitch, between the base of the needle clusters and the stem and which they maintain

even after burrowing inside. Particles of a poison dust applied before hatching of the larvae would be present under the web, thus accounting for the reduction in injury to trees dusted at this particular period.

PARASITES

With the introduction of the tipmoth into the plantations at Halsey a few of its parasites were probably also brought in. The most effective parasites, however, were presumably left out, inasmuch as the tipmoth in other places is controlled largely by high percentage of parasitism. It has been thought that introduction of parasites, reared from material collected in a region where the pest is held in check largely by this agency, would probably bring in the more effective species. If conditions were favorable for their development in Nebraska, they would eventually reduce the tipmoth to a point where their work would not be serious. A more thorough study of local parasites would show what species were present, their abundance, and effectiveness in different tree species.

a. Local parasites.

Between 8 and 10 species of parasites and predatory insects were found to be working on the tipmoth at Halsey. The species are not all determined but specimens have been sent to Washington for specific determination. The list included 2 or 3 Ichneumonidae, 2 Braconidae, 4 or 5 Chalcidoidea, and 1 predaceous beetle. Two species of the Chalcidoidea, Haltichella sp. and Eurytoma sp., were the most numerous local parasites. Next in number came two species of Braconidae. These belong to the genus Microbracon and are probably gregarious.

To obtain information on local parasites, infested tips were collected from 3 separate western yellow pine plantations, 200 tips from each, and the moths and parasites reared. A collection of 200 infested tips was made in a jack pine plantation several days after moths had

started to emerge. A count on the trees showed that about 10% had already emerged but it is doubtful if any parasites were lost as they were several days behind the moths in emerging. The number of moths lost is added to those reared and the total given in the table under jack pine.

Table V.

Rearings from local pine tips.

Lot #.	Plantation	No. moths	No. parasites	Approx. % of parasitism
1	Western yellow pine	209	20	8.7
2	" " "	213	33	13.4
3	" " "	120	21	14.9
4	Jack pine	110	67	37.85

The average per cent of parasitism in western yellow pine, figured from the total number of insects reared, was 12.33% while in jack pine it amounted to 37.85% for the single lot. These percentages are of course only approximate as one of the parasites is gregarious and a few of the larvae, pupae, or parasites might have died in the tips.

The higher percentage of parasitism in jack pine may be one of the reasons for the small amount of injury in this species besides its abundance of tips and ability to overcome terminal injury. The abundance of parasites is probably due to the small size of the buds and shoots as compared with western yellow pine, thus making the tipmoth larvae and pupae more accessible to the parasites.

b. Introduced parasites.

Mr. R. A. Cushman of the National Museum at Washington, was in charge of parasite introduction. In 1924 Mr. Cushman made a study of parasites

of the pine tipmoth (Rhyacionia frustrana) in the vicinity of Washington, determining the species and which were primary and secondary. In June 1925 parasite material was collected near Falls Church, Virginia, in Virginia scrub pine, and brought to Halsey by Mr. Cushman. Parasites began to emerge on June 25th and continued until July 26th. Each species was kept separate and those that were primary parasites were liberated in various plantations of western yellow pine. Liberations were made every day throughout the emergence period in plots separated from each other by a quarter of a mile or more. Each plot was assigned to a particular species.

A total of 2384 individuals were released, covering 8 separate species, 1 Tachinidae, 2 Ichneumonidae, and 5 Chalcidoidea. Five more species of primary parasites, also several secondary, were reared but not in sufficient numbers to warrant liberation. Three of the above, including the most abundant species liberated, Eurytoma tylodermatis, was already present at Halsey. The following table gives the total number of each species liberated at Halsey in 1925.

Table VI

Parasites liberated at Halsey, Nebr., 1925.

Species	No. released
Lixophaga mediocris & plumbea	52
#Cremastus epagoges	15
Campoplex sp.	369
#Eurytoma tylodermatis	1437
#Haltichella sp.	254
Hyssopus sp.	238
Secodella sp.	6
Habrocytus thyridopterigis	13
Total	2384

- indicates species present at Halsey.

The isolation of each introduced parasite species will make it possible to study more carefully the tendencies of each: adaptability, rapidity of spread, efficiency when working alone with the local parasites, and efficiency when mixed with the other species.

PERMANENT PLOTS

Many factors may influence the abundance of insects and the amount of damage they do. The discovery of one or more of the controlling factors may lead to definite control measures, or at least to the reduction of the infestation. With the pine tipmoth a number of factors, outside of climatic conditions, might be influential: Susceptibility of tree species, ability to outgrow injury, distribution and abundance of the pest, height of trees, age of trees, site, and source of seed.

The influence of practically all of these factors can best be studied by establishing permanent plots in suitable locations. This work was started and a number of 100-tree plots staked out in plantations of various ages scattered over the forest. On each plot the following data were recorded: Location, species, age, approximate number per acre, source of seed when known, total height, annual height growth for last three years, total number of tips per tree, per cent of terminal buds killed, number of lateral buds killed by tipmoth.

The data are not yet sufficient to give the relative influence of all of the factors and not in form to give summary of totals. However, a number of facts are shown in these and other observations. Western yellow pine is by far the most susceptible to tipmoth injury and in the extensive plantations of this species is found the principal injury: loss

of height growth, misshapen trees, encouragement of peridermium rust gall fungus, and in come cases actual death of the trees. Jack pine and Scotch pine are not as susceptible as the former species due, perhaps, to several reasons - lack of attraction, numerous tips as compared to western yellow, ability to overcome terminal injury, heavier parasitism, and small size of buds and shoots. Austrian pine was practically immune from tipmoth injury from observations made during the past season. The tipmoth is present in all parts of the forest but no damage is evident until several years after planting when the trees are about a foot or more in height and appear above the grass. Western yellow pine after reaching a height of 10 feet or more is seldom retarded in height growth as there is little or no injury to the upper tips. Less than 2% of the nursery stock was affected by tipmoth injury this year, and under 3% the year before as indicated by counts made in the field. No pupae were found wintering in the tips, apparently all spin cocoons in the soil.

Conclusions and future plans

Summing up the facts presented in this report, the status of the tipmoth problem at Halsey is as follows:

This insect is so serious in the plantations at Halsey, particularly in yellow pine, that the development of some method of control is imperative. The accomplishment of this purpose is difficult but by no means impossible. A number of leads are being followed at present and doubtless others will open up as the investigations progress.

Due to the fact that the pest has been distributed throughout practically all the plantations which have received nursery stock from the Bessey nursery, one of the most pressing needs is to find some method by which the nursery stock can be thoroughly cleaned of infestation before it leaves the nursery. Although the eggs of the moth have not actually been found on the transplants, it appears probable that it is in this stage that the insect is carried on the young trees, since the moths of the first brood are flying at the time of digging in the spring. Of course, it is possible that a very small proportion of the larvae or pupae overwinter in the tips, but the few individuals that might do this would not account for the general infestation of plantations.

It is of course possible that the moths themselves fly or are blown long distances and thus become widely distributed. The possibility of this has been discounted in the past and it still seems somewhat improbable inasmuch as the moths are low flyers and do not take wing readily during periods when there is much of a breeze. It is important, however, that this point be determined, and experiments are being planned with this end in view.

Experiments during the past season have shown that the cleaning of the nursery stock is feasible. Further experiments testing the most promising methods on a larger scale will be carried on next summer. In connection with this work next year, a small experimental plantation of cleaned stock should be set out at a distance of several miles from the nearest plantation to test the efficacy of the treatment.

If it is found that the moths do not fly far and when a practical method of cleaning the nursery stock is perfected, then it would be desirable to establish planting operations at as great a distance from the present plantings as possible. In this way, these plantings may be kept free from infestation until they are no longer susceptible to serious injury, but such a step should not be taken until such time as its success appears reasonably certain.

The use of nicotine dust as a contact insecticide and calcium arsenate as a stomach poison did not prove sufficiently promising against this pest to warrant further experiments with these materials.

During the past season the introduction of parasites into the Bessey plantations and the study of parasites already present has been carried on. The fact that eight species of parasites are already established in the plantations reduces somewhat the probability that the introduction of additional parasites will prove effective. It is possible, however, that the most effective parasites are not present.. Therefore it is highly desirable that studies of the life history and ecological relationships of tipmoth parasites be immediately started. This work should be carried on in an area where a yellow pine infestation of the tipmoth is being heavily parasitized. The Black Hills region might well offer a favorable location for a part of this work. (See Mr. Higgins' memorandum) It is doubtful if any further indiscriminate introduction of parasites is justified under the circumstances. Careful observations of the activities

of both native and introduced parasites should be continued at Halsey to determine whether or not the introduced species are becoming established, how much they have spread from the central point of liberation and how they are competing with other species, both local and introduced.

Observations on the effect of site, species, age, density, weather, and other factors on the tipmoth which are being carried on by means of sample plots have not as yet produced much in the way of results. It will be necessary to increase the number of plots and carry the observation over a series of years.